What Makes Teachers Change?
Factors that Influence Post-secondary Teachers' Adoption of New Computing Curricula

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Introduction

Over the past several years, learning sciences researchers have shown growing interest in topics on fostering the implementation and dissemination of innovations derived from learning sciences research (Dede, 2006; Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; Fishman, Penuel, & Yamaguchi, 2006). Research on these topics is dedicated to making innovations emerging from the learning sciences community have real-world impact on teaching practices and thereby students' learning. To this end, it is crucial to understand what factors influence the change in teaching practices—the adoption, adaptation, and further implementation of educational innovations.

Teachers, the practitioners of teaching, play fundamental roles in nearly all formal instructional systems (Borko, 2004). Therefore, teachers are regarded as a "cornerstone" or "the most influential factor" in educational innovations (Driel, Beijaard, & Verloop, 2001; Fishman & Davis, 2006) Given the key role of teachers in the implementation of innovations, we attempt to examine teachers' perceptions of adoption factors for curriculum innovations, especially the concerns and challenges they perceive when considering adoption, and how they explain their adoption decisions.

In this paper, we focus on one specific innovation—contextualized computing curricula, which are a series of contextualized introductory Computer Science (CS) courses offered for undergraduates to encourage diversity and to improve the enrollment and retention of students in CS. Informed by related learning theories, these courses focus on the learning of computing skills and concepts in terms of motivating domains where computing is useful, such as digital media & robotics (AnonForReview, 2006). In our past work, we found contextualizing the computing education has had a dramatic impact on student retention and motivation (AnonForReview, 2005a). However, as many curriculum innovations in other subjects do, we are facing the problem of the inconsistency between the positive reactions of teachers towards innovations and the fact that the same teachers do not bring those innovations into their classrooms.

Solving this problem requires a deeper understanding of the essence of the problem: What factors affect teachers' adoption of curriculum innovation? The teachers we address here are in university settings, which give us a different research context than similar teacher change research (Fishman, 2006; Kubitskey & Fishman, 2005). To explore this question, we propose a theoretical model to represent our hypotheses, and conducted a series of pilot studies to validate the model, which might inform researchers to devise effective strategies for removing barriers that prevent teachers' adoption of curriculum innovations.

Theoretical Framework and Literature Review

Related work

Although it is well-known that teachers play a crucial role in efforts to implement curriculum innovations, teachers' role can be examined from different perspectives. Recent work on teacher change and curriculum innovation has suggested a bottom-up approach instead of the traditional top-down innovation model (Driel et al., 2001; Fincher & Tenenberg, 2007; Richards, Gallo, & Renandya, 1999). In a traditional top-down innovation model, teachers are usually blamed for the failure of an innovation, where change is viewed as the transmission of ideas from curriculum developers or researchers to teachers (Fincher & Tenenberg, 2007; Levy & Ben-Ari, 2007). In contrast, the bottom-up or more teacher-oriented approach suggests that the role of teachers in curriculum innovation is not merely executing the innovative ideas of others. In fact, the change of teaching practice relies on the change of teachers' knowledge and beliefs (Driel et al., 2001; Kubitskey & Fishman, 2005; Richards et al., 1999). Furthermore, Teachers' knowledge and beliefs are deemed as key elements in the interaction of Professional Development (PD) and teaching practice (Borko, 2004; Kubitskey & Fishman, 2005). These elements, on one hand, can be changed through PD and teaching practice and, on the other hand, serve as critical factors that impact teachers' decisions about implementing innovations (Kubitskey & Fishman, 2005; Putman & Borko, 1996).

All these insights suggest that, to understand the role of teachers in curriculum innovations, teachers' knowledge, attitudes and beliefs be analyzed. In addition, the teachers we address here are teachers in higher education, with unique features compared to teachers in K-12 settings. On one hand, most of them rarely receive formal education either in theory and methods of the profession as a teacher, or practical training during the actual work of teaching. On the other hand, they usually have much freedom in deciding their own teaching practices. Therefore, it is critical to understanding their existing knowledge, attitudes and beliefs and, furthermore, how these elements may influence their teaching practices. Specifically, this paper takes a teacher-oriented perspective to examine how and what kind of knowledge, attitudes and beliefs influence CS teachers' adoption of curriculum innovations, as well as other related issues perceived by teachers as potential adoption factors.

Related research has also identified a variety of content and forms of teachers' knowledge and beliefs in general (Calderhead, 1996; Putnam & Borko, 1996). One important category is pedagogical content knowledge and beliefs—knowledge and beliefs that are specially related to teaching a specific subject. Expanded by Grossman (Grossman, 1990), pedagogical content knowledge and beliefs include four central components: "conceptions of purpose for teaching a subject matter", "Knowledge of students' understanding and potential misunderstanding of a subject area", "Knowledge of curriculum and curricular materials" and "Knowledge of strategies and representations for teaching particular topics" (Putnam & Borko, 1996).

In this paper, our discussion of teachers' knowledge, attitudes and beliefs focuses on how these elements affect teachers' adoption of curriculum innovation. As (Dede, 2006) suggested, we assume that a relatively small set of contextual factors are often very influential in determining the decision of adoption. With reference to the four components of pedagogical content knowledge and beliefs, we will propose specific themes about CS teachers' knowledge attitudes and beliefs as potential adoption factors in the next section.

Theoretical Framework: Teacher Change Model

Based on related work, we assume that teachers' knowledge, attitudes and beliefs will influence their adoption decisions by affecting their understanding and beliefs toward a new approach (or curriculum), especially their perception of the "fit" or alignment of their needs and what the new approach offers, as well as their confidence in enacting that approach. This kind of perception and confidence will determine whether they would like to adopt that new approach. On the other hand, the PD activities serve as one intervention that may impact these factors.

In particular, we propose four categories of factors that may influence teachers' adoption decisions of reforms (called Adoption Factors): I. Teachers' knowledge, attitudes and beliefs about curriculum; II. Their knowledge, attitudes and beliefs about students; III. Their knowledge, attitudes and beliefs about self (the teacher); IV. Quality of intervention (PD activities such as workshops, conferences and other teacher education opportunities). Teachers' knowledge, attitudes and beliefs about curriculum, students and self are personal factors from teachers, and PD activities serves as an external factor that intervene to change in those knowledge, attitudes and beliefs.

Knowledge, Attitudes and Beliefs about Curriculum

Knowledge, attitudes and beliefs about curriculum involve issues that relate to teaching a specific course, such as how a teacher understands and believes what to teach in that course, how to teach, and correspondingly to what extent they agree with those related ideas of a new approach.

- *Learning goals*—what is this course for? For example, what a CS teacher thinks the goals of an introductory CS course should be, or, whether she believes a new approach fits with those goals and will work in practice.

- *Content coverage.* This theme involves what kind of content a teacher believes this course should cover, and whether a new approach meets that content coverage requirement. Particularly, a CS teacher may also care about the programming language used or taught in that course, e.g. should I use Java or Python to teach an introductory CS course?

- *Preparation time.* Teachers may worry about how much preparation time is necessary to invest when using another approach to teach.

- *Particular ideas conveyed by the new approach.* Teachers may hold different attitudes towards particular ideas implied in a new approach. For example, considering a contextualized computing course, are they convinced of the role of context in motivating students' learning?

Knowledge, Attitudes and Beliefs about Students

Knowledge, attitudes and beliefs about students specifically focus on teachers' beliefs in students' interests and abilities to learn a course in an innovative way.

- *Students' interest.* For instance, do they believe that using media manipulation as a context to teach an introductory CS course will appeal to students?

- *Students' abilities.* Some teachers may worry that students do not have sufficient background knowledge to learn a course using a new approach, while others are confident in their students' abilities to learn it easily.

Knowledge, Attitudes and Beliefs about (Teacher) Self

Knowledge, attitudes and beliefs about self relate to teachers' perception of the need to change, their interest in change as well as beliefs in their own abilities to change.

- *Perception of the need to change*. Is the teacher satisfied with how she currently teaches the course? Or, does she think she needs to adopt new approaches to improve her teaching?

- *Personal interest in change.* Does she feel interested/ active in trying a new approach?

- *Confidence to change.* Does she feel confident in her ability to implement a new approach?

Quality of PD Activities (Intervention)

Although our discussion mainly focuses on those personal adoption factors from CS teachers, PD activities do serve as an important intervention, which to some extent contribute to the change in those knowledge, attitudes and beliefs participants hold, especially when reform ideas are effectively disseminated through PD activities. For example, a series of successful workshops with strong leaders or presenters and sufficient resources usually help to convince the participants of the reform ideas.

Methods

Context

Our study was conducted in the context of one specific innovation—contextualized computing curricula. One major problem of current approaches for teaching introductory CS courses is lack of relevance (Margolis & Fisher, 2002). Computer Science is perceived as irrelevant, boring and difficult (AAUW, 2000). We are offering a series of contextualized introductory CS courses for undergraduates, which emphasize contexts that students recognize as being authentic and relevant for computing to encourage diversity and to improve the enrollment and retention of students in CS (AnonForReview, 2005b). These contextualized courses include Introduction to Media Computation in Java or Python, Media Computation Data Structures in Java, Engineering in MATLAB, and Robotics in Python.

Our goal is to construct a situation where students are engaged in what they perceive to be Legitimate Peripheral Participation (Lave & Wenger, 1991) for a Community of Practices that they recognize as valuable (AnonForReview, 2006). We create such a construction by providing a single context for the course that pervades lectures, examples and homework. A *context* is a theme that students recognize as being relevant for the course content. For example, students recognize digital media manipulation or robotics as real-world situations where computing plays a role, and students value those real-world situations as occurring for their desired community of practices. There are similarities between contextualized computing education and project-based learning (Blumenfeld et al., 1991). In our case, the theme (the "driving question") crosses multiple student projects for an entire term.

Related past work shows contextualizing the computing education has had a dramatic impact on student retention and motivation (AnonForReview, 2005a, 2005b). We attempt to disseminate these curriculum innovations through an NSF "Broadening Participation in Computing" alliance, focused on increasing the number and diversity of computing students in our local state. The rest of this paper addresses our efforts to understand and predict when our efforts at dissemination are successful.

Pilot Study

We conducted a pilot study through three summer workshops to examine those proposed adoption factors in the teacher change model. During the workshops, we gathered information about teachers' existing knowledge, beliefs and attitudes as well as perceived adoption concerns from pre- and post- workshop surveys and discussions. This information was used to predict teachers' possible decisions of adopting approaches from workshops to classrooms. In fall 2007, we distributed adoption decision surveys to get information of teachers' actual decisions, which were then compared with our predictions.

In pre-workshop survey, we asked twelve general questions about their attitudes and beliefs towards computing curriculum, students and self, especially on teachers' interest in change, the need to change, the role of context, the need to attract students, and students' ability to learning CS, which were repeated in the post-workshop survey. In the post-workshop survey, twelve questions about each approach were asked around those themes in the model. In particular, we added questions related to innovative ideas implied in these new courses, such as CS relevance and the roles of context. In addition, open-ended questions were included in the surveys on how they understand the role of context in teaching introductory CS courses, what challenges they perceived when considering adoption, what unique needs of their students or school situation didn't get addressed in the workshop. Meanwhile, during the workshops, participants had a 45-minute discussion about what kind of adoption concerns they had. In the adoption decision survey, participants were asked adoption decisions as well as their reasons for those decisions.

Data Collection

In summer 2007, three summer workshops on these new approaches were offered. The Media Computation Workshop was open to all CS teachers, while the other two workshops were limited to local State System faculty, introducing all the five new courses. Overall, thirty participants in the three summer workshops filled out both pre- and post- workshop surveys: five faculty from three universities in May workshop, eighteen teachers from seventeen universities in June workshop and seven faculty from four schools in July workshop. Twenty four of them also filled out the adoption decision surveys at the beginning of fall 2007 semester.

Measures/Analysis

Both qualitative and quantitative analysis techniques were applied to identify potential variables in the model as well as the correlations between teachers' adoption and different variables. First, based on data from post-workshop surveys and in-workshop discussions, we elicited common themes of adoption concerns and compared them to the variables proposed in the theoretical teacher change model. Since our sample is pretty small, we included all the variables reported by participants. We also compared teachers' responses to the twelve common questions in both pre and post surveys. We used regression analysis to examine the correlation between adoption decisions (as the dependant variable, 0-No, 1-Yes) and teachers' general beliefs and attitudes (as independent variables, including the twelve general statements, from 1-Strongly Disagree to 5-Strongly Agree). Furthermore, motivation and barriers for actual adoption were generated from teachers' explanations for their adoption decisions.

Findings

Workshop Evaluation

After the workshops, teachers (n = 24) showed their interest in new approaches (M = 4.76, SD = .702) and felt the need to change (M = 4.13, SD = .680). They were also convinced in the positive role of context for introductory CS courses (M = 4.46, SD = .588) and felt excited in using context to teach introductory CS course (M = 4.29, SD = .624). However, we found small changes in their knowledge, attitudes and beliefs towards computing curriculum, students and self through the workshops. Although, the change through the workshops is not statistically significant, the workshops still played a role. Sixteen teachers answered whether their attitudes and opinions about teaching introductory CS courses changed through the workshops, reporting four aspects of change: half of them mentioned they were more convinced in the importance/benefits of using a context teaching CS; five of them became more excited in or committed to implementing the new courses; three of them felt the need to change the current teaching approaches; two of them were more confident in adopting these courses.

Perceived Adoption Concerns

Through post-workshop surveys, participants expressed their concerns about adopting those approaches by answering what challenges they perceived when considering using any of the introduced approaches and what were the unique needs of their students or school situation not addressed. Results from the surveys are summarized in Table 1. We included all the variables reported by participants in the surveys to get a general idea of those adoption concerns from teachers' eyes. In addition, during the workshops, participants discussed the challenges of contextualized computing education and their concerns when adopting these courses into their own schools. Overall, these discussions indicate similar results as reported in the surveys.

As we can see from Table 1, teachers reported a variety of adoption concerns, which offered a few specific examples of adoption factors related to their personal knowledge, attitudes and beliefs curriculum, students and themselves. One big challenge perceived is to get students prepared to learn a contextualized computing course since students may lack background knowledge in math, media or other areas related to the context. Some of them even worried about the low quality of students in their schools. As for teachers themselves, the most common concern reported was about "confidence to change". When adopting a new course, teachers need to spend time learning the materials and working on lectures and lab assignments. It might require extra effort when they need to adapt those tools or course materials to fit their own needs. Moreover, it is also a challenge to become proficient in delivering the content especially when they have limited background knowledge of a context.

Comparing these perceived adoption concerns to the proposed theoretic change model, we find most of those variables are well covered by the proposed model with some additions. In addition to these personal concerns, four categories of external variables were reported that we did not propose in the original model (see the "Other" part of Table 1): technical supports, course materials package, faculty development and organizational restrictions. First, it was reported as a big challenge to get colleagues to embrace the context or the new approach to teach. Second, organizational restrictions may bind teachers' hands. Thirdly, teachers were challenged to get all of the software tools used in a new approach to work. Moreover, sufficient resources of course materials that are easy to grab will contribute to their confidence in adoption.

Table 1. Adoption Concerns Perceived by CS Teachers

Themes	**Frequency**
About Curriculum	**7 (total)**
Fitting a new approach into current curriculum	1
Content for both CS majors and non-majors	1
Covering generally required course content	3
Collaboration across disciplines	2
About Students	**12 (total)**
Personal interest in the context	3
Preparation (limited background knowledge, low level of knowledge sophistication)	7
Limited time for completing assignments	2
About teachers/themselves	**12 (total)**
Preparation time	3
Adapting the tools / course materials to local environment	5
Becoming proficient in delivery/articulation	3
Interest in the context	1
Other	**11 (total)**
Technical supports: getting specialized software tools (for a new approach) to work	2
Course materials package (e.g. textbooks, lecture slides)	2
Faculty development	5
Organizational restrictions: No programming language/textbook choice or funding	2

for specialized resources	

Adoption Results: Facilitators and Inhibitors

Adoption Results

As fall 2007 semester began, twenty-four teachers reported their adoption decisions on the contextualized computing courses introduced in the summer workshops. Fifteen (62.5%) of them adopted/adapted one or more courses into localized classrooms. We successfully predicted fourteen of the adopters. The adopters used the new course materials or approach (es) in different ways: nine teachers adopted to modify an existing course, three other teachers used it to replace an existing CS1 course, and another four teachers created a brand new course in their schools. On the other hand, among the nine non-adopters (37.5%), five of them didn't adopt as we predicted.

Motivation for Adoption

Teachers also explained for their adoption decisions from different perspectives. First, the easy-to-use feature of the software introduced in these courses is one facilitator of adoption. Secondly, the biggest motivation for adoption came from their beliefs in those basic ideas of the contextualized computing courses, especially the potential role of context in promoting learning. Especially, for the "unexpected" adopter, predicted as non-adopter due to the issue of having required programming language to teach, reported adapting our Java courses for her current C++ courses since she thought teaching CS in context would help students to grasp CS concepts better. In fact, about half of the adopters said they adopted because the new course(s) would help to motivate their students:

> I feel that it's very important to motivate the students to learn and this approach seems to satisfy that concern.
>
> My motivation is motivation--I think our students will be motivated to work harder when their programs give them cool results.

In addition, teachers' prior experiences played a role in convincing teachers to adopt. Some of them found the ideas conveyed in the workshops were connected to their prior teaching experiences, which convinced them in adopting those courses, as one teacher said:

> I have always struggled with how best to motivate students to learn computer programming. For the past year, I have experimented with teaching Objects-First with a heavy emphasis on graphics and GUIs. I had some success with this approach last spring. After seeing [one of the authors] is doing, media computation seems to be a natural migration for the way I teach the CS1 class.

Barriers for Adoption

On the other hand, teachers' explanations for their non-adoption decisions further extended our proposed model. Unsurprisingly, teachers did not adopt due to their personal concerns on the course content and preparation time as well as being unconfident in working on the new course materials. Nevertheless, the main barriers (more than half of the non-adopters reported) to adoption came from organizational issues: the tension of convincing their colleagues to use a new approach, or overcoming the department curriculum restrictions (e.g. to use a different programming language, or teach the same course in a different way).

> The other two people teaching the class wanted to unify the material taught to the students and neither of them is informed on the Media Computation approach.
>
> Actually, I personally would like to adopt both the Media Computation Course as well as the sequel Media Computation Data Structures Course. However, I am still working to convince other members of my CS Discipline Committee.

In particular, for those teachers who did not adopt as predicted, the inhibitors for them are respectively the issues related to the course content, preparation time, working on course materials, unified department curriculum, or required programming language to teach.

Regression Results

Using regression analysis at entry-level of $P < .05$, we failed to build a significant regression model for our small-sized data. Using $P < 0.1$ as enter criteria, we got a regression model with a low *R Square* of .397, which means that only 39.7% of the change in adoption decision can be explained by the change in the independent variables. Three variables existed in this final regression model with biggest influence on adoption decision: teachers' excitement in using context ($\beta = .749$; $SE = .281$; $p = .015$), CS relevance to students' lives ($\beta = -.521$; $SE = .215$; $p = .025$), and confidence in current teaching ($\beta = .567$; $SE = .262$; $p = .042$). Teachers' excitement in using context and confidence in their current teaching has positive influence on their adoption of those contextualized courses. Nevertheless, teachers' belief that CS is relevant to students' lives has negative effect on adoption, which is not expected by our model, suggesting further examination of this factor. This finding also highlights the significant role of teachers' excitement, which was also clued in both the perceived adoption concerns and reported adoption reasons, as stated by participants:

> Can faculty with no interest in Media Computation be dragged (successfully) into teaching using the Media Computation approach?
>
> [It's] fun, interactive approach. It was fun for me, so I'm sure the students will enjoy it too.

Discussion

In this paper, we take a teacher-oriented perspective to examine potential adoption factors, from teachers' eyes. As other researchers of educational innovation implementation have found in the K-12 system (Fishman et al., 2004), similar systemic issues exist in our context too. Although the dissemination of curricula in higher education is not as hierarchical as in the K-12 system, each department usually has its curriculum committee (consisting of a few faculty) to intervene what courses to teach, especially for a general introductory course. Therefore, we believe the department curriculum issue might be common for lots of schools. It's also not surprising that convincing other colleagues becomes another adoption issues for many teachers.

On the other hand, our pilot study results suggest teachers' interest plays a positive role in motivating them to adopt curriculum innovations. Teachers might become interested in *the specific course content or learning activities in the new curriculum*, e.g. manipulating media in an introductory CS course. From a learning sciences perspective, teachers are also learners (Fishman & Davis, 2006), who need motivation as well. Teachers' excitement in a new curriculum has the magic to drive teachers to try it out, to help them make sense of it, and finally to convince them to adopt it. Broadly speaking, exciting teachers could be a powerful strategy for facilitating teachers' adopting of curriculum innovations. Furthermore, several variables that facilitate adoption suggested by our study can be summarized into teachers' perception of coherence (Fishman et al., 2006)—seeing the connection between their own prior experiences and goals, and what the innovative approach offers. For example, a teacher is more likely to adopt, when she see the merits of an introductory to media computation course, which is consistent with what she is seeking for—motivating students.

Although external factors are usually not controlled by adopters themselves and are difficult to change, they do affect how teachers perceive the feasibility of adoption. Therefore, teachers may face multiple obstacles to adoption. Their adoption decisions are influenced not only by their individual knowledge and beliefs about curriculum, students and self as well as related PD, but are also affected by those external variables such as technical supports, resources, faculty development and other organizational restrictions. As PD leaders and facilitators, we need to work closely with teachers to address their concerns and thereby provide an influential level of supports and resources. *PD normally can not directly remove systemic issues for teachers*. When dealing with the extensions between teachers' control and systemic restrictions, possible strategies might include explicating the importance and merits of the innovations, exciting teachers, and offering sufficient resources and other supports, so that teachers can overcome organizational issues.

This pilot study was conducted with a small-sized sample, focusing on a relative subset of adoption factors, which is not completely sufficient to test the proposed teacher change model. For example, although we recognize the importance of PD, we did not specifically examine PD features. In addition, our data is generated from a small-sized sample. Therefore, in the future, we will further validate this model through follow-up studies. We plan to modify and extend this pilot study in a second round of workshops as well as to conduct a follow-up study to track teachers' adoption status in a longer term.

Conclusion

Our findings extend and refine our proposed teacher change model. Teachers' knowledge, attitudes and beliefs play a significant role in affecting adoption decisions by influencing how teachers perceive the "fit" or alignment of their needs and what the new approach offers for their local classrooms. Systemic issues and technical/resources supports do matter for post-secondary teachers as well, which might prevent adoption, while teacher excitement helps to motivate adoption. This model is presented and discussed in the context of contextualized computing curriculum, but it is not limited in computing curriculum innovations. This model, as we continue to refine it, might offer a basis for PD developers and facilitators to devise effective strategies for removing barriers that prevent teachers' adoption and implementation of curriculum innovations.

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References

AAUW. (2000). *Tech-Savvy: Educating Girls in the New Computer Age*. New York: American Association of University Women Education Foundation.

AnonForReview. (2005a). Title removed for blind review. In *Proceedings of the 36th SIGCSE technical symposium on Computer science education* (pp. XXX-YYY). New York ACM Press.

AnonForReview. (2005b). Title removed for blind review. *IEEE Transactions on Education 48*(2), XXX-YYY.

AnonForReview. (2006). Title removed for blind review. In *ICER '06: Proceedings of the 2006 international workshop on Computing Education Research* (pp. XX-YY). New York: ACM Press.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3/4), 369-398.

Borko, H. (2004). Professional development and teacher learning: mapping the terrain. *Educational Researcher, 33*(8), 3-15.

Calderhead, J. (1996). Teachers: beliefs and knowledge. In D. Berliner & R. Calfee (Eds.), *Handbook of educational psychology* (pp. 709-725). New York: Macmillian.

Dede, C. (2006). Scaling up: Evolving innovations beyond ideal settings to challenging contexts of practice. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 551-566). New York: Cambridge University Press.

Driel, J. H. v., Beijaard, D., & Verloop, N. (2001). Professional Development and Reform in Science Education: The Role of Teachers' Practical Knowledge. *Journal of Research in Science Teaching, 38*(2), 137-158.

Fincher, S., & Tenenberg, J. (2007). Warren's question. In *Proccedings of Third International Computing Education Research Workshop (ICER)* (pp. 51-60). New York: ACM.

Fishman, B., & Davis, E. (2006). Teacher learning research and the learning sciences. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 535-550). New York: Cambridge University Press.

Fishman, B., Marx, R. W., Blumenfeld, P., Krajcik, J., & Soloway, E. (2004). Creating a Framework for Research on Systemic Technology Innovations. *The Journal of the Learning Sciences, 13*(1), 43-76.

Fishman, B. J., Penuel, W. R., & Yamaguchi, R. (2006). *Fostering innovation implementation: findings about supporting scale from GLOBE*. Paper presented at the International Conference on Learning Sciences.

Grossman, P. L. (1990). *The making of a teacher : teacher knowledge and teacher education*. New York: Teachers College Press, Teachers College, Columbia University.

Kubitskey, B., & Fishman, B. J. (2005). *Untangling the relationship(s) between professional development, practice, student learning and teacher learning*. Paper presented at the Annual Meeting of the American Educational Research Association.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation* Cambridge, UK: Cambridge University Press.

Levy, R. B.-B., & Ben-Ari, M. (2007). We work so hard and they don't use it: acceptance of software tools by teachers *ACM SIGCSE Bulletin, 39*(3), 246-250.

Margolis, J., & Fisher, A. (2002). *Unlocking the Clubhouse:Women in Computing*. Cambridge, MA: MIT Press.

Putnam, R., & Borko, H. (1996). Learning to teach. In D. Berliner & R. Calfee (Eds.), *Handbook of Educational Psychology* (pp. 673-708). New York: Macmillian.

Richards, J. C., Gallo, P., & Renandya, W. A. (1999). Exploring teachers' beliefs and the processes of change. Retrieved 11/11, 2007, from http://www.professorjackrichards.com/pdfs/exploring-teacher-change.pdf.